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TOXICITY REDUCTION EVALUATIONS IN MUNICIPAL WASTEWATER TREATMENT

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16. ABSTRACT

A policy to develop water-quality-based permit limitations for toxic pollutants entering treatment plants is being developed because, even with efficient removal of conventional pollutants, significant amounts of toxic substances are being discharged through the Nation's wastewater treatment systems. To support the policy of water-quality-based permit limitations on toxic pollutants, an overall water-quality-based toxic control process is evolving. A key step in this overall control process is a Toxicity Reduction Evaluation (TRE) at an individual municipal or industrial wastewater treatment plant.

After a toxics water quality problem is confirmed at a plant, the TRE (which involves an integrated monitoring approach employing both specific chemical and bioassay techniques) (1) evaluates the toxicity reduction occurring across the plant and determines the probable cause of the excessive toxicity in the discharge (2) traces the toxicity to its source and, at the same time, identifies the components, if possible, and (3) evaluates control alternative to eliminate the excessive pass-through.

Some data from a toxicity reduction survey of six Ohio municipal wastewater treatment plants are given. The progress on toxicity reduction research suggests that the TRE concept may be an affordable approach to solve the site-specific problems of toxicity discharges by treatment plants.

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INTRODUCTION

The U.S. Environmental Protection Agency (EPA) is establishing a National "Policy for the Development of Water-Quality-Based Permit Limitations for Toxic Pollutants." The EPA national policy is being developed because of data indicating that, even with efficient removal of conventional pollutants, toxic substances in amounts significant to water quality are being discharged through the Nation's wastewater treatment systems. An overall water-quality-based toxic control process[1] is evolving to support the policy of water-quality-based permit limitations on toxic pollutants entering treatment plants. The toxic control process will include procedures for evaluating toxics problems in receiving waters, for locating and identifying the responsible point source discharges and for controlling, equitably and cost-effectively, the toxic discharge to eliminate the water quality problem.

Research on toxics in wastewaters by the EPA has revealed that water quality problems associated with point source discharges of toxics exhibit extensive site-specific factors including the amounts, types and sources of toxics, the control effectiveness of existing treatment plants and the characteristics and dilution capacity of the receiving water. Unfortunately, solutions to such water quality problems have complex site specific aspects.

In addition, in the past, the study of toxic discharges into receiving waters by treatment plants had focused chiefly on specific chemicals.[2,3] The complexity of many wastewaters, especially municipal wastewaters involving multiple industrial components, however, has also forced the use of biological measurements[4,5] for assessing ecosystem toxicity (overall ecosystem toxic effects) and potential health effects of these wastewaters. Thus an integrated monitoring approach using both specific chemical and bioassay techniques is evolving for evaluating toxics water quality problems. The monitoring, especially by bioassays on plant effluent, provides sensitive screening for identifying potential toxic impacts from plant discharges.

A key step in the overall toxics control process is called a Toxicity Reduction Evaluation (TRE) at individual municipal or industrial wastewater treatment plants. Initiated after confirmation of a toxics water quality problem, the TRE, also using an integrated monitoring approach at the treatment plant, determines the toxics sources, the toxics fate during and impact on treatment, the variability of pass-through of the overall toxicity in the effluent wastewater and finally the probable solutions for controlling the toxicity discharge.

The TRE protocols for use by the wastewater treatment industry are now being developed through the EPA's Office of Research and Development by research teams at the Andrew W. Breidenbach Environmental Research Center in Cincinnati. The purpose of this paper is to describe the overall approach of a TRE and to present the progress of the ongoing research to develop the TRE concept for municipal wastewater treatment.

THE TOXICITY REDUCTION EVALUATION

The biomonitoring screening of point source discharges and the follow-on studies, to confirm and evaluate the impact of the toxic discharge on the receiving water, establish the control requirements for the TRE at the treatment plant. The control requirements usually are presented as integrated toxicity levels that must be achieved by the point source discharge to eliminate the toxic water quality impact. Such levels will ultimately be established using a statistical approach that will be based upon desired water quality and the historical variability of the receiving water flow or dilution capacity.

With the desired toxicity levels established for the discharge, the overall elements of a typical TRE at the treatment plant are presented in Table 1. The first step is the evaluation of the toxicity reduction occurring across the treatment plant and the determination of the probable cause of the excessive toxicity in the discharge. A key determination is whether operational deficiencies at the plant significantly contribute to the toxicity pass-through or whether the presence of toxicity refractory to the plant's treatment processes principally produces the excessive toxicity.

The next step in the TRE involves two elements, occurring in parallel, in which the toxicity is traced to its sources and the important toxicity components, if possible, are identified. Ecosystem and the health effect biomonitoring assays, in-plant toxicity monitoring assays, and specific chemical analytical techniques are all employed to achieve the goals of this step.

Finally, an evaluation of the control alternatives to eliminate the excessive pass-through is conducted. The evaluation includes assessing possible industrial process modifications to minimize release of the toxics, the use of pretreatment approaches to control the toxics before discharge to the central plant, and improvement of the central plant's operations to control the toxicity.

TABLE 1. ELEMENTS OF A TOXICITY REDUCTION EVALUATION

- Treatment Plant Evaluation of Causes of Toxicity Pass-Through.
  - A. Plant Operations Deficiency.
  - B. Presences of Refractory Toxicity.
- Tracing of Toxicity to Sources.
  - A. Bioassay Monitoring
  - B. Alternative Monitoring Techniques
- Identification of Toxicity Components.
- Evaluation of Control Alternatives.
  - A. Industrial Process Modifications.
  - B. Pretreatment Alternatives.
  - C. Central Treatment Plant Control of Toxicity.

RESEARCH APPROACH AND PROGRESS

The research approach to develop appropriate protocols on TRE for use in municipal wastewater treatment involves:

- Toxicity reduction studies on pilot and full-scale treatment systems to determine representative toxicity reduction capabilities of municipal wastewater treatment processes.
- Case histories of research TRE at selected full-scale treatment plants to assess the capabilities of the monitoring tools and the treatability and pretreatment approaches likely to be incorporated in the municipal protocols for TRE.
- Research on techniques to enhance the toxicity reduction capabilities of the central treatment plant.

Parallel research is also ongoing on TRE protocols and case histories for industrial wastewater treatment. The parallel research will include the assessment of approaches for industrial process modification to minimize toxicity release. These industrial techniques will be appropriately referenced in the protocols on the municipal TRE.

TOXICITY REDUCTION CAPABILITIES

Pilot-scale research using wastewater spiked with representative toxic mixtures has revealed a good capability of the central treatment plant to reduce toxicity, but toxicity penetration into the plant effluent does occur. Before describing the results of the pilot scale studies and other studies at full-scale, the method used to calculate the percent toxicity reduction across treatment plants needs to be described. Percentage removals of toxicity can be determined by (1) calculating toxicity units for the influent and effluent wastewaters from their respective lethal concentrations or effect concentrations at the 50 percent level (LC_{50} or EC_{50}) (equation 1) and (2) calculating the percentage toxicity reduction (equation 2).

$$\text{Toxic unit (T.U.)} = 1/LC_{50} \qquad (1)$$

$$\text{\% Toxicity Reduction} = \frac{\text{T.U. of Influent} - \text{T.U. of Effluent}}{\text{T.U. of Influent}} \times 100 \qquad (2)$$

As an example of the treatment plant capabilities, acute toxicity reductions of 100 percent based upon Fathead Minnow bioassays[6] were achieved in a pilot-scale primary activated sludge treatment plant for the indigenous (metals and organics) toxicity in an industrialized raw Cincinnati wastewater. The spiking at 50 µg/L levels of each compound in a mixture of 22 of the Agency's

priority organic pollutants[7] into the same wastewater, however, produced an increase in the toxicity of the raw wastewater and substantial pass-through, even with acclimation, of residual toxicity (Table 2). Selected compounds, most importantly lindane in the spike, were refractory to the treatment processes. High conventional pollutant removals[2] were always achieved during this study, independently of the spiked toxics.

Pilot and full-scale studies[5], using Ames[8] and mammalian cell[9] assays have revealed the presence and pass-through of mutagenic materials in municipal wastewaters. The mutagenic materials were extracted from several Cincinnati wastewaters with methylene chloride, first at pH 2, then at pH 11. The concentrated extracts were combined and solvent transferred into dimethyl sulfoxide (DMSO) to eliminate the effect of methylene chloride on the subsequent

TABLE 2. ACUTE TOXICITY* IN WASTEWATER TREATMENT

Control System			Spiked System**		
LC-50 percent Inf.	Eff.	% Toxicity Reduction	LC-50 Percent Inf.	Eff.	% Toxicity Reduction
30	100	100	4.6	13.1	65
11	100	100	2.7	16.1	83
9.3	100	100	9.5	35.5	73
30	100	100	4.5	6.6	32
10.2	100	100	4.3	9.4	55
18.5	100	100	5.8	30	81
10.1	100	100	6.5	30	78
20.6	100	100	1.9	8.0	76

*Fathead Minnow acute toxicity.
**Spiked with 22 priority organics.

mutagenicity assays. The results of the Ames assays (Table 3) revealed substantive but variable amounts of mutagenicity in the influent wastewaters, ranging to approximately 20,000 revertants per liter.

The mutagenicity removals in these tests with efficient conventional treatment, varyed from substantive removal to essentially no removal of the mutagenicity. This study and others also revealed that wastewaters of domestic origin have low extractable mutagenicity levels, usually around 500 revertants per liter of effluent.

The high number of not detectable (N.D.) responses in these studies on the raw wastewaters or primary effluents are usually caused by cytotoxic effects from the large amounts of extracted organics in the extract. Unlike the secondary effluent tests, the cytotoxic effects prevented testing of the extracted organics from the raw or primary wastewater over an appropriate concentration range to properly evaluate the mutagenicity. Additional tests with mammalian cell assays[9] using Syrian hampster cells reveal qualitatively similar responses between the two assays. The results from the mammalian cell assays suggest higher removals of mutagenicity measured by the mammalian cell compared with the results from the Ames test.

Currently, the assay results from the Ames test or other health effects screening assays cannot be related to health effects risk. Research, currently ongoing, will need to successfully establish a link between health risks and the screening assay results before the screening health effects assays can be appropriately incorporated into the regulatory toxic control process.

TOXICITY REDUCTION SURVEY

A toxicity reduction survey is now being completed at six municipal wastewater treatment plants in the State of Ohio. The plants were selected for the survey to represent wastewaters of chiefly domestic origin, wastewaters with modest industrial contributions, and wastewaters with substantial industrial contributions. The toxicity entering and leaving the treatment plants were measured using static renewal seven-day acute-chronic Fathead Minnow[10] and Ceriodaphnia [11] assays for assessing ecosystem effects, the Ames test and mammalian cell assays cells for mutagenicity screening, and the Sister Chromatid Exchange assay[12] using Chinese hampster ovary cells for genotoxicity. Analyses of conventional pollutants and of specific toxics for trace metals and individual organics were also provided. The State of Ohio's Environmental Protection Agency also conducted fish diversity studies using electroshock techniques on the receiving waters associated with some of the treatment plants.

Examples of representative toxicity reduction for ecosystem effects are shown in Tables 4 and 5 for the wastewater treatment plant at Akron, Ohio and the Little Miami Plant in Cincinnati. The Akron Plant, with substantive industrial contributions to the wastewater, exhibited the highest influent toxicity of all the surveyed plants with no effect concentrations (NOEC)

TABLE 3. MUTAGENICITY IN THE AMES TEST OF MUNICIPAL WASTEWATER SAMPLES AT VARIOUS TREATMENT STAGES

Treatment Plant	Wastewater Type	Sample Designation (Date)	Treatment Stage	Total Liters Extracted	Conc.[a] (mg/L)	TA98 Mutagenicity			TA100 Mutagenicity		
						net revertants/mg		net[b] revertants/liter	net revertants/mg		net[b] revertants/liter
						-S9	+S9		-S9	+S9	
Mill Creek T&E Facility	Industrial/ Domestic	Series A_1 09/02/81	Raw Wastewater	2	48.8	173	381	18,593	N.D.	N.D.	-
			Primary Effluent	2	41.8	1,057	524	21,903	N.D.	N.D.	-
			Secondary Effluent	6	4.9	169	1,376	6,674	N.D.	258	1,251
			Secondary + Cl_2	6	4.6	196	1,768	8,133	N.D.	409	1,881
		Series A_2 09/09/81	Raw Wastewater	2	66.5	N.D.	182	12,103	N.D.	N.D.	-
			Primary Effluent	2	46.0	77	392	18,032	N.D.	N.D.	-
			Secondary Effluent	6	4.6	5,645	4,074	18,944	1,836	1,035	4,813
			Secondary + Cl_2	6	4.0	6,370	4,318	17,272	2,246	2,146	8,584
Mill Creek Plant	Industrial/ Domestic	Series B_1 08/31/82	Raw Wastewater	8[c]	91.0	N.D.	89	8,099	N.D.	N.D.	-
			Secondary Effluent	50[c]	7.7	417	353	2,718	N.D.	244	1,879
		Series B_2 06/20/83	Primary Effluent	23	70.4	N.D.	129	9,082	N.D.	N.D.	-
			Secondary Effluent	86	8.7	693	761	6,621	928	1,540	13,398
Muddy Creek Plant	Domestic	Series C_3 01/11/83	Raw Wastewater	24[c]	36.8	N.D.	N.D.	-	N.D.	N.D.	-
			Secondary Effluent	92[c]	2.2	161	175	385	208	284	625

N.D. = not detectable (i.e. response at any sample dose level was less than 2-fold above concurrent solvent control).
[a]Refers to the concentration of extractable organics based on the residue weights of the extracts.
[b]Based on the mutagenicity values from the assays with S9 activation.
[c]Extraction at pH 11.0 was omitted.

TABLE 4. TOXICITY REDUCTION AT AKRON NO EFFECT CONCENTRATIONS,* PERCENT EFFLUENT

	Fathead Minnows				Ceriodaphnia			
	Survival		Growth		Survival		Reproduction	
	8/84	5/85	8/84	5/85	8/84	5/85	8/84	5/85
Influent	<0.3	1.0	0.3	1.0	0.3	1.0	0.3	1.0
Secondary Effluent	30	10	10[a]	30	≥30	30	30	30
Chlorinated Secondary	10	10	≥100[b]	≥100	30	≥100	30	30
Dechlorinated Secondary	≥100	10	≥100[b]	30	30	≥100	30	30

[a] - CL_2 may have been present in sample.
[b] - Low control value, NOEC may be lower.
*All NOEC data are subject to final statistical review.

TABLE 5. TOXICITY REDUCTION AT LITTLE MIAMI NO EFFECT CONCENTRATIONS,* PERCENT EFFLUENT

	Fathead Minnows				Ceriodaphnia			
Sample	Survival		Growth		Survival		Reproduction	
	12/84	5/85	12/84	5/85	12/84	5/85	12/84	5/85
Influent	10	10	10	10	3	10	0.3	3
Secondary Effluent	≥100	≥100	30	30	1	10	1	3
Chlorinated Plant Effluent	30	30	30	30	1	10	1	3
Dechlorinated Plant Effluent	30	30	30	30	1	10	3	3

*All NOEC data are subject to final statistical review.

ranging from 0.3 to 1 percent of the influent wastewater. The Akron plant, which was achieving nitrification and meeting its conventional pollutant removal requirements during the survey, also achieved efficient toxicity removal with the NOEC ranging from 10 percent of the effluent for acute (survival) effects on Fathead Minnows to 100 percent effluent for acute (survival) effects on both the Fathead Minnow and the Ceriodaphnia assays. The typical NOEC of 10 and 30 percent in the Akron effluent suggests a discharge of only modest toxicity to the receiving water ecosystem.

The Little Miami Plant, with modest industrial contributions to its wastewater, exhibited less toxicity in the influent wastewater but also achieved little toxicity reduction across the treatment plant. The NOEC of 1 to 10 percent effluent in the Little Miami effluent for the Ceriodaphnia assay were the most toxic of the effluents evaluated in the survey, even though the plant was meeting its conventional pollutant removal requirements. Finally, the data presently available on plants in the survey with wastewaters of chiefly domestic origin revealed modest toxicity in the influent and essentially no ecosystem toxicity in the effluent.

To assess the probable effect of the effluent on the receiving stream, however, the stream dilution capacity must be considered. For the Akron Plant, the effluent contributes more than 50 percent of the stream flow during summer low flow conditions. In contrast, the Little Miami effluent provides less than 1 percent of the flow to the Ohio River, even at summer low flow conditions. With substantive dilution, the Little Miami toxicity discharge is unlikely to affect the Ohio ecosystem. The effluent dominated Cuyahoga River at Akron, however, could be affected by the modest toxicity discharges from the Akron Plant.

The fish diversity studies (Figure 1) on the Cuyahoga River, indeed, indicated a major toxic impact on the fish population beginning at the point of discharge of the Akron Plant. Upstream of the discharge, the fish population was found to be good. The fish populations in the River's tributaries also, usually ranged from fair to good. The fish diversity study, conducted three times during the Summer of 1984 and spanning the time of the toxicity survey, revealed a persistent loss of fish in the Cuyahoga for about 10 miles down stream of the Akron discharge and a second toxics impact when the River entered the Cleveland Ship Channel at Lake Erie. No other significant wastewater discharges enter the Cuyahoga immediately below Akron, as the River passes through the Cuyahoga National Park Recreational Area. In addition, appropriate measurement of stream dissolved oxygen (D.O.) and ammonia concentrations revealed no D.O. or ammonia toxics impacts on the River immediately below Akron. Overall, the stream fish diversity indicated major toxicity impacts on the River, perhaps the most significant impacts in the State of Ohio.

Other data obtained during the survey revealed no significant metals concentration (Table 6) and very modest concentrations of specific extractable organic residuals in the Akron plant's effluent (Table 7). In addition, the relatively complex GC chromatograms on the highly toxic plant influent, and the relatively "clean" GC chromatograms of the effluent (Figures 2 and 3) supported the observed efficient toxicity reduction achieved by the treatment

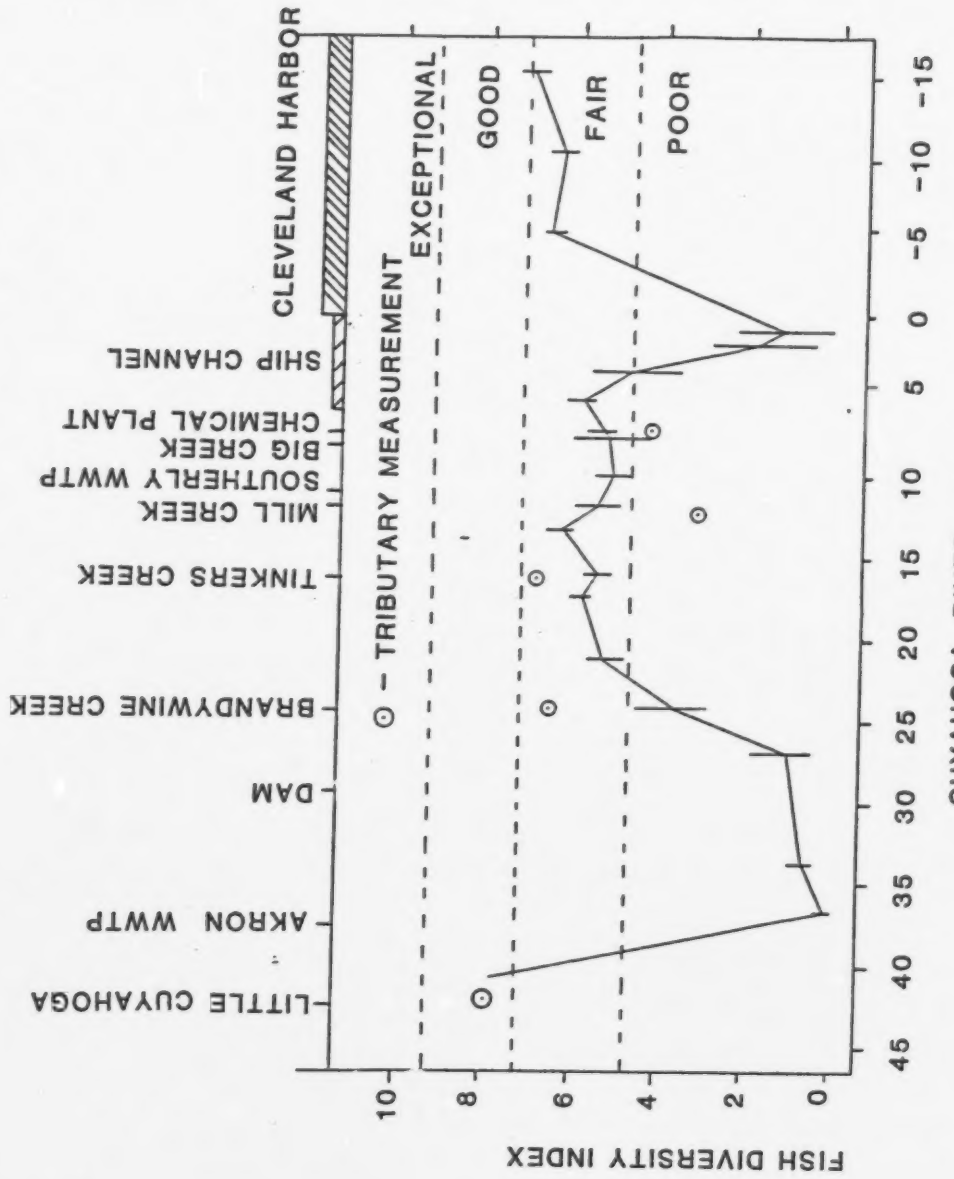

Figure 1. Toxicity impact on the Cuyahoga River.

TABLE 6. AKRON METALS REMOVAL

Metal	Concentration mg/L					
	1984		1985			
	Inf.	Eff.	Inf.	Eff.	Up Stream	Down Stream
As	BDL*	0.0077	BDL	BDL	BDL	BDL
Ca	90.3	75.8	95.6	72.1	65.1	67.6
Cd	0.0012	BDL	0.028	0.0094	0.0041	0.0097
Cr	.088	.016	BDL	BDL	BDL	BDL
Cu	0.19	.026	.029	.011	BDL	BDL
Fe	0.28	0.17	2.14	0.913	0.583	0.633
Mg	22.7	14.5	24.2	16.5	15.7	16.5
Mn	0.204	0.102	0.417	0.313	0.200	0.165
Ni	0.34	BDL	0.022	0.013	0.0062	0.010
Pb	0.057	BDL	0.046	BDL	BDL	BDL
Zn	0.447	0.038	1.333	BDL	BDL	BDL

*BDL - Below detection limit.

TABLE 7. EXTRACTABLE ORGANIC ANALYSIS OF AKRON CHLORINATED SECONDARY

No.	Compound	µg/L
1	d(10)anthracene	Internal. Std.
2	formamide, n,n-dimethl-	8
3	ethene, tetrachloro-	65
4	1,6-hexanediol	10
5	1-cyclohexen-1-ol	7
6	2-cyclohexen-1-one	4
7	benzaldehyde	6
8	unknown	5
9	unknown	4
10	hydrocarbon	3
11	hexane	2
12	unknown	2
13	5-hexen-2-ol	7
14	benzothiazole	4
15	unknown	2
16	unknown	24
17	unknown	2
18	unknown	2
19	unknown	5
20	hexanedioic acid, bis(2-ethylhexyl) ester	50
21	bis(ethylhexyl)phthalate	7
22	unknown	2

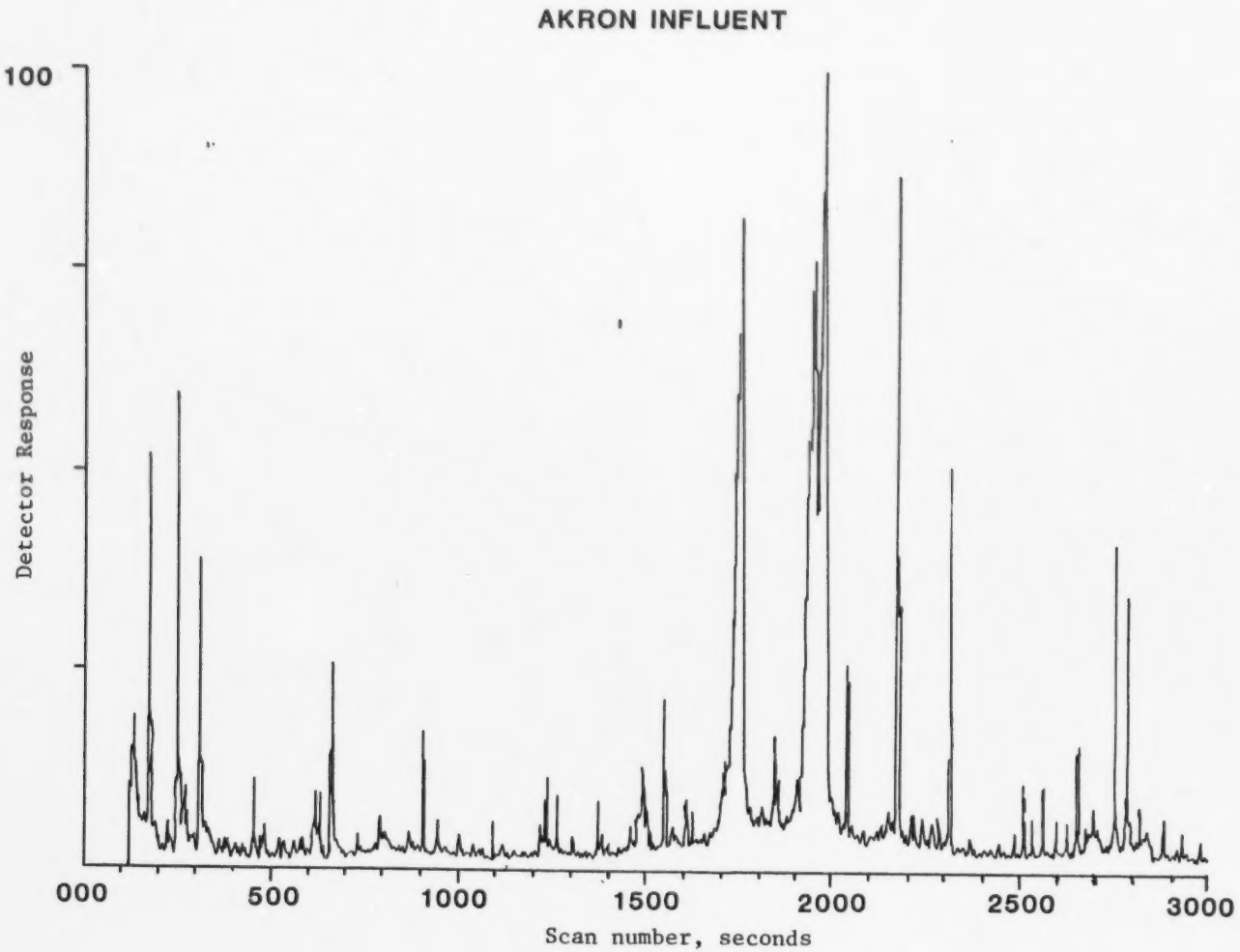

Figure 2. Total ion chromatogram on raw wastewater.

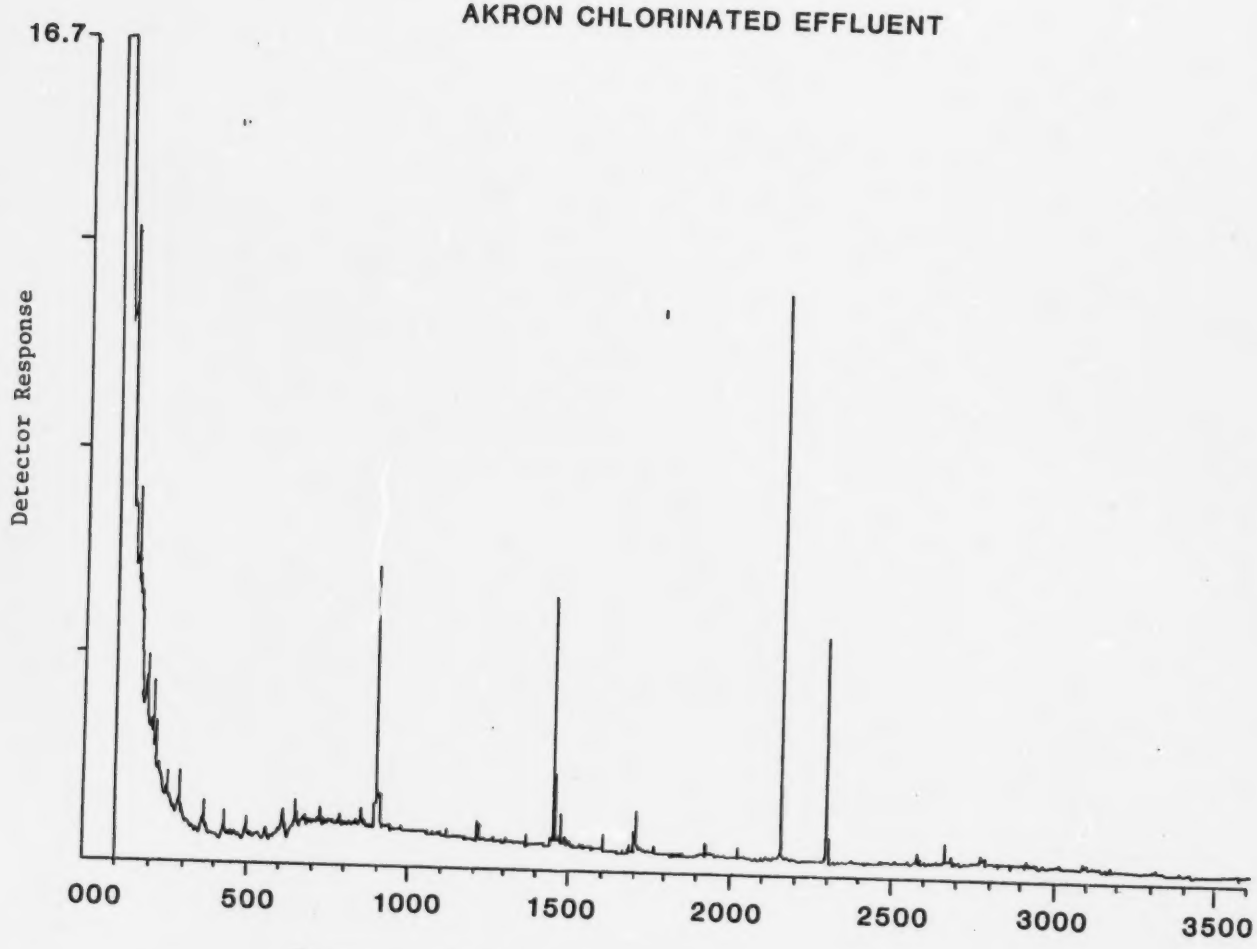

Figure 3. Total ion chromatogram on plant effluent.

plant. Further, the Ames test screening for mutagenicity (Table 8) also revealed only modest mutagenicity in the effluent, indeed not significantly different from effluents from plants treating chiefly domestic wastewater. Unfortunately, because the plant's influent is highly toxic its mutagenicity could not be determined.

The modest toxicity in the Akron effluent with the relatively "clean" wastewater, as measured by residual metals and specific extractable organics, raised questions about the sources of the toxics causing the observed and persistent loss of fish in the Cuyahoga River at Akron. Thus, studies to measure variability of the effluent toxicity, to reconfirm the lack of fish in the River, and to identify responsible specific toxics in the effluent are being conducted this summer.

Finally, a preliminary review of the plant's operating records has also revealed intermittent bypassing of combined sewer flows at the treatment plant. Indeed, the bypassing of the highly toxic plant influent could represent the most important contribution to Cuyahoga's toxicity problem at Akron. A full-scale TRE, as a research case history, is now under consideration for Akron. The decision to use Akron as a detailed case history will follow the review of the ongoing confirmatory studies on the toxicity impact.

TABLE 8. AKRON MUTAGENICITY STUDY

Sample (1984)	Concentration of Extractable Organics mg/L	AMES REV/mg	Mutagenicity Rev/L
Raw Wastewater	45.09	NS	----
Secondary Effluent	3.66	140	512
Chlorinated Secondary	3.02	130	393

TRE CASE HISTORIES

Two case history studies on TRE's are about to begin. The first case history, to begin this Fall, is at the Patapsco Wastewater Treatment Plant in Baltimore, Maryland. The second case history will likely be a TRE at Akron, if the ongoing confirmatory studies confirm the need.

The Patapsco Wastewater Treatment Plant, completed in 1982, is a 70 mgd pure oxygen activated sludge plant, currently treating 35 mgd at design conditions using one-half the plant's treatment capacity. The industrial contribution to the Patapsco municipal wastewater, chiefly from the organic chemicals industries in Baltimore, currently totals about 30 percent of the plant influent. The case history TRE for Baltimore was selected not only because of substantive influent toxicity at the treatment plant and a history of intermittent pass-through of that toxicity (Tables 9 and 10) but also because of a historical and ongoing in-plant toxicity monitoring and control program.

Two sources of wastewater, a chiefly industrial flow (IPI) and a flow (SWD) from domestic-commercial sources are combined to form the plant influent. The in-plant monitoring MICROTOX procedure[13] on daily composite samples at the plant uses a maximum of 45.5 percent wastewater in the test. For low toxicity levels that require more than 45.5 percent wastewater to produce a measurable EC_{50}, the EC_{50} of the sample was recorded as >45.5 percent. Thus, the low toxicity effluents and the domestic-commercial influent flows (SWD) do not always have a definitive EC_{50}. To provide the monthly average perspective given in Table 9, EC_{50} values of >45.5 percent were included in the monthly averaging procedure as 45.5 and the monthly average EC_{50} in the table was presented as a greater than (>) value. The number of days in the month that an EC_{50} lower than >45.5 occurred is also included in Table 9. The averaged monthly EC_{50} values

TABLE 9. MICROTOX TOXICITY AT PATAPSCO

1985	IPI[a] INF. Avg. EC_{50}[c]	SWD[b] INF. Avg. EC_{50}	COMBINED INF. Avg. EC_{50}	EFFLUENT Avg. EC_{50}
Jan.	3.0	> 18.2 (27)*	16.5	> 41 (7)*
Feb.	2.7	> 34.5 (12)*	26.6	> 35.3 (17)*
Mar.	3.6	> 33.9 (18)*	18.2	> 25.8 (26)*
Apr.	3.2	> 33.9 (20)*	12.8	> 34.7 (18)*
May	5.8	> 16.4 (27)*	9.4	> 36.0 (16)*
Jun.	8.2	> 13.4 (29)*	9.4	> 40.7 (12)*

[a]IPI, plant influent chiefly from industrial sources.
[b]SWD, plant influent from chiefly domestic-commercial sources.
[c]EC_{50} is given as percent effluent.
*Number of days, the EC_{50} was less than >45.5 during each month.

for the effluent are all less than >45.5 and indicate a toxicity pass-through during each month. The number of days that measurable toxicity pass-through occurs ranged from 7 days per month to 26 days per month.

The limited ecosystem bioassay toxicity developed by the EPA on Patapsco plant effluents (Table 10) qualitatively confirmed the variability and pass-through of toxicity indicated by the routine MICROTOX measurements. The results suggest that a desirable statistical link between the pragmatic in-plant monitoring and the expensive Agency ecosystem bioassay may be developed.

Effective toxic control at treatment plants require inexpensive monitoring tools that can preferably respond in real time and be used in monitoring approaches to provide warnings of potential toxic impacts or pass-through before the toxics reaches the treatment plant. The specific chemical,[14,15] bioassay toxicity[6,16] and health effects[1] screening tools, currently recommended by the Environmental Protection Agency for the water-quality-based toxic control process, require relatively long measurement times with multi-step procedures. The practical functions of these EPA recommended tools in a TRE are as monitors of the plant's discharge requirements and as linkage to probable receiving water effects and to waste load allocation procedures.

Although limited by their costs, these Agency bioassays could also be used in the development of monitoring approaches for warning of potential toxic plant impacts or pass-throughs and for tracing toxics to their source. However, less expensive and simpler monitoring tool, are more desirable for effective routine in-plant and in-sewer toxic monitoring.

TABLE 10. EPA BIOASSAY EVALUATION OF THE EFFLUENT AT THE PATAPSCO PLANT

	Fathead Minnow*		Ceriodaphnia**	
Assay Test	Acute	Chronic	Acute	Chronic
3/8 - 15/84	100% Mortality IN 100% Effluent	NOEC at 30% Effluent	100% Mortality in 3% Effluent	NOEC at 0.37% Effluent
6/23/84	45% Mortality in 100% Effluent	--	100% Mortality in 10% Effluent	--
7/13-20/84	No Mortality at 100%	None up to 6% effluent	100% Mortality at 30% effluent	None up to 6% effluent

*Seven-day Early Life Stage Growth Test using Fathead Minnow.
**Ceriodaphnia Seven-day Life Cycle Toxicity Test.

In November 1980, the City of Baltimore in anticipation of potential industrial toxic impacts during the start-up and operation of its new activated sludge treatment process at the Patapsco Plant began monitoring its wastewaters for toxicity using the 5-minute MICROTOX[13] analyses. The City ultimately will expand its evaluation to three candidate in-plant monitoring approaches for the TRE study at its Patapsco Wastewater Treatment. These in-plant monitoring tools for indicating the presence of toxicity are the Beckman MICROTOX analyzer with a fluorescent bacteria, respirometry (oxygen uptake) measurements[17,18] on the plant's biomass, and Adenosine Triphosphate (ATP) measurements. These inexpensive monitoring tools have near real-time responses ranging from actual real-time for the TOXIGARD respirometry alternative to about a 1-hour response time for the ATP measurement.

The overall objectives of the planned case history TRE at the Patapsco Plant are given in Table 11. These objectives emphasize use of the pragmatic in-plant monitoring methods and the development of a link between the near real-time measures and the Agency's ecosystem bioassays used in the toxics regulatory process.

TABLE 11. PATAPSCO TOXICITY REDUCTION EVALUATION

Research Objectives:
° Evaluate toxicity reduction across plant using MICROTOX, Respirometry and ATP
° Summarize specific chemical inventory across plant (organics and metals)
° Assess techniques to identify and trace toxicity to sources
° Evaluate link between in-plant monitoring and ecosystem bioassays
° Assess treatability of wastewater for toxics control as related to plant design
° Develop techniques to minimize toxicity pass-through

SUMMARY

The progress on the toxicity reduction research suggests that the TRE concept, with protocols, has substantive potential to support the wastewater treatment industry's efforts to solve the site specific problems of toxicity discharges by treatment plants. Indeed, the TRE concept with the pragmatic in-plant monitoring tools may be the only affordable approach for managing complex mixtures of toxics, especially in municipal wastewaters.

Key procedures for efficient tracing of the toxicity to its source, identifying the principal components of the toxicity, and demonstrating practical control responses to eliminate excessive toxicity discharges, however, have not yet been sufficiently tested at full-scale treatment plants to confirm the ultimate utility of the concept. Research on approaches to improve the operation of municipal plants for toxic control also has not yet been initiated. The EPA will diligently pursue these remaining research needs to confirm the TRE concept and, thereby, improve the Nation's ability to control toxicity water quality problems from point source discharges.

The use of data in this paper from the ongoing research effort in Cincinnati, Ohio, is appreciated and acknowledged.(19)

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